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*PRISTIPOMOIDES FILAMENTOSUS*  
(F. LUTJANIDAE), AND ASSOCIATED  
FISHES, *TOWNSEND CROMWELL*  
CRUISE TC-90-10, 1990**

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## ABSTRACT

Eighty bottom trawls were conducted from the NOAA ship Townsend Cromwell (cruise TC-90-10, 28 November-13 December 1990) at 11 windward and leeward regions of Oahu, Molokai, Lanai, and Maui to characterize depth-distribution patterns of opakapaka, *Pristipomoides filamentosus*, and associated fishes. The trawls produced 89 taxa of benthic and epibenthic fishes. The most commonly trawled benthic species was a lizardfish, *Trachinocephalus myops*. The highest mean catch per unit effort (CPUE; number per trawl) was recorded from catches at Kaneohe Bay (224 benthic fish/trawl). Juvenile opakapaka occurred in only 12 trawls, with a total of 125 individuals collected; 108 of these were collected off Kaneohe Bay. Length frequencies of opakapaka were bimodally distributed. The precision of the mean CPUE data from the trawls was insufficient to detect 50% changes in the abundance of either opakapaka or three other major species.

## INTRODUCTION

Exploratory fishing was initiated in 1988 to identify the habitat of juvenile eteline snappers (Lutjanidae) in Hawaii (Parrish 1989). The results of that study and evidence from Struhsaker (1973) suggest that juvenile pink snapper or opakapaka, *Pristipomoides filamentosus*, inhabit relatively flat, featureless bottoms at depths of 61-130 m, with few specimens caught at greater depths. Data on the regional variation in depth distributions and on the locations of habitat for juvenile opakapaka are lacking. These data are necessary to fully understand the extent and importance of opakapaka nursery habitat throughout the main Hawaiian islands (MHI).

Our report primarily summarizes the fish catch data collected during a bottom trawl survey conducted from the NOAA ship *Townsend Cromwell* (cruise TC-90-10) and characterizes the benthic and epibenthic fish fauna associated with juvenile opakapaka from these data. Secondly, our report describes the depth distribution patterns of juvenile opakapaka throughout the MHI and evaluates the precision of data on catch per unit effort (CPUE; number caught per trawl) for estimating the abundance of opakapaka and major associated fishes.

## MATERIALS AND METHODS

### Sampling

Bottom trawls were conducted from the NOAA ship *Townsend Cromwell* (TC-90-10, 28 November-13 December 1990) using two identical, single-warp, 12.2-m semiballoon shrimp trawl nets with wing and other body dimensions proportional to a 22.6-m balloon trawl net (Fig. 1). The bottom trawls used 15-m headropes with six 15-cm cork floats and four additional 25-cm metal floats, and 12-m footropes with fifteen 15-cm plastic roller floats. A tickler chain and a 0.675-cm cod-end liner were used throughout the survey. The bottom trawls also used 1.4 by 2.0 m otter boards to keep the mouth of the net open during the trawls. Trawling depth was recorded by time-depth recorders (TDRs) and by a chromascope depth-sounder aboard the *Townsend Cromwell*. The TDRs were attached to the headropes of the trawls.

Eighty bottom trawls (52 night trawls and 18 trawls for the day-night series) were completed at 11 windward and leeward regions of the MHI (Fig. 2; Table 1), of which 72 (90%) were quantitative tows (QTs). A trawl was defined as non-quantitative (NQ) if the gear was lost or broken or if the tow deviated from the desired bearing or depth or was aborted; all other trawls were quantitative. Regions were chosen based on historical evidence for juvenile opakapaka (Struhsaker 1973). At each



region, one to six trawls were made at one to three bottom depths (shallow: 61 m; mid-depth: 76 m; deep: 91 m; Appendix A). Tow speeds ranged from 1.32 m per second (mps) to 2.63 mps; the mean speed of QTs was 1.94 mps. Mean duration of QTs was 22 minutes  $\pm$  5.6 SD (range, 12-33 minutes). Tow track lengths were less variable than tow durations. Changes in sea state and in the condition of the otter boards required adjustments in tow speeds or durations to maintain approximately constant tow distances. Tow distances ranged from 1.74 to 3.12 km. The mean distance of QTs was 2.51 km  $\pm$  0.26 SD (Appendix B). A standard unit of effort, equal to a constant tow distance of 2.51 km, was assumed in all CPUE calculations.

Several series of day-night trawls were conducted off Oahu (Haleiwa and Kaneohe Bay) and off Molokai (southeast (SE) Penguin Bank; Fig. 2) for diel comparisons of catch-at-depth. However, many trawls were NQ, and complete series of six day and six night trawls were not completed at the three regions because of rough seas and gear loss. Three day and six night QTs were completed at SE Penguin Bank, and five day and two night QTs were completed at Haleiwa. No QTs were completed at Kaneohe Bay for the day-night comparisons.

### Types of Data

The total number and cumulative biomass (kilograms wet weight) of fish caught were recorded for each trawl. Invertebrates were counted, weighed, and preserved in formalin for later identification; results will be reported elsewhere. Opakapaka were measured to the nearest 0.1 cm fork length (FL) and frozen whole for later age-at-length determination. Fish were classified to the lowest identifiable taxa. Questionable species were verified through references (Appendix C). The number (and biomass if aggregate weight of individuals of a species was  $>0.01$  kg) of individuals was also recorded by taxon and by region.

### Statistical Power Analysis

It was assumed that future comparisons of CPUE data from trawls with prior series of data similar to ours would use a Student's *t*-test or other similar statistical test. Therefore, we used our trawl data to estimate the power of *t*-test comparisons of means for opakapaka at Kaneohe Bay, and for each of three other species for all regions combined, in order to determine whether a 50% change in CPUE could be detected. This criterion of 50% has precedence in environmental monitoring studies (e.g., Skalski and McKenzie 1982). All depths were pooled within each region. Data were transformed to common (base 10) logarithms, then the effect size (ES) was calculated:



$$ES = 0.301/SD,$$

where  $0.301 = |\pm 50\% \text{ difference in } x|$  for log-transformed catch data. Tables 2.3.5 and 2.4.1 in Cohen (1988) were used to determine the requisite number of trawls at  $\beta = 0.20$ , power  $(1 - \beta) = 0.8$ , and  $\alpha_2 = 0.05$ .

## RESULTS AND DISCUSSION

The trawls yielded 89 taxa of benthic and epibenthic fishes (Appendix D). Individual fish totaled 4,411 in the 72 QTs; 229 individuals were also caught in the 8 NQs. Thirty-five percent of the cumulative catch was caught in the 5 trawls made off Kaneohe Bay, and over 78% in 28 trawls at 4 different regions off Oahu. The CPUE decreased noticeably if data from the day trawls were included. Prior studies (see review by DeMartini and Allen 1984) have indicated that diversity (species richness) is generally greater and variations in CPUE are less in night than in day trawls. Henceforth, the data for diel-comparison trawls are omitted from our CPUE comparisons.

The most numerous fish caught (1,401 individuals in 40 of 72 QTs) was a myctophid, *Benthosema fibulatum*, comprising 32% of the total catch (Appendix E). However, it was excluded from our abundance and biomass comparisons, because observations of Reid et al. (1991) suggest that it is a land-associated mesopelagic species rather than a benthic species. Other species known to be meso- or epipelagic also were deleted (one *Astronesthes* sp.; six opelu, *Decapterus macarellus*). The epibenthic pufferfish *Lagocephalus hypselogeneion* ranked first in frequency caught for all regions pooled, because of the large numbers caught at Kaneohe Bay and Laie (Fig. 3C-D). *Lagocephalus hypselogeneion* also ranked first in total weight (73.89 kg) if elasmobranchs were excluded (Appendix F). Otherwise, a stingray, *Dasyatis* sp., ranked first in biomass (three specimens weighing an estimated 95 kg).

The highest CPUEs were recorded off Kaneohe Bay and Laie, with means of 224 fish/trawl and 149 fish/trawl, respectively (Table 2). Catches were more variable at Laie than at Kaneohe Bay. Lahilahi Point, leeward Oahu, had the lowest CPUE of all the regions, with a mean of 3 fish/trawl (Table 2). The mean CPUE data of top-ranked species by number of individuals are illustrated for 8 of the 11 regions in Figure 3. Trawl CPUE data for the other three regions were negligible. A synodontid, *Trachinocephalus myops* ranked first in abundance at 6 of the 11 regions and second at 2 of the remaining 5 regions. Of the other top-ranked species, only *Lagocephalus hypselogeneion* (top-ranked in 6 of 11 regions) and the bothid *Engyprosopon xenandrus* (top-ranked in 8 of 11 regions) commonly occurred.



When the regions were pooled by depth, *Trachinocephalus myops* was the most abundant species in the deep trawls (Table 3). Moreover, it was commonly encountered (15 trawls at 8 of 10 deep regions and 18 trawls at 8 of 10 mid-depth regions). *Lagocephalus hypselogeneion* was most abundant in mid-depth trawls and was also commonly encountered (11 trawls at 7 of 10 deep regions and 9 trawls at 5 of 10 mid-depth regions). No species was both abundant and frequently encountered at the shallow depths. The sandlance *Bleekeria gilli* was the most abundant fish in the shallow trawls, but occurred in only two of six trawls (at one of three regions, Laie). Other species were too variable between regions and trawls for us to speculate on patterns of abundance. An apparent difference in CPUE, with all species combined, between mid-depth and deep trawls (cf. Table 2) was not supported by statistical comparison (Wilcoxon signed-ranks test;  $T = 9$ ,  $N = 8$  pairs,  $P > 0.05$ ). Species richness appeared greater in the deep (54 species) and mid-depth trawls (60 species) than in the shallow trawls (15 species), but this may reflect the variability in the number of trawls at each depth.

### Juvenile Opakapaka

Juvenile opakapaka occurred in only 12 (17%) of the 72 QTs at 5 of the 11 regions fished. A total of 125 opakapaka were collected; 108 (86%) of these were caught in the 5 QTs made off Kaneohe Bay. The second largest catch of juvenile opakapaka occurred off Laie (eight fish in one of six trawls). All of the opakapaka were juveniles. The distribution patterns of opakapaka in the windward and leeward regions were not compared because of insufficient data. The length-frequency distribution of the opakapaka was markedly bimodal (Fig. 4). This is thought to represent two age classes of fish: Age-1+ juveniles from a 1989 spawning, and 6-month-old (age-0+) juveniles from a mid-1990 spawning (R. Moffitt, Honolulu Laboratory, unpubl. data; R. Humphreys and K. Landgraf, Honolulu Laboratory, unpubl. data). Juvenile opakapaka smaller than 8-cm FL were conspicuously absent from our trawls, as in prior hook-and-line collections made at Kaneohe Bay (R. Moffitt, unpubl. data).

Juvenile opakapaka were caught most frequently in trawls ranging from 64-80.1 m deep (Fig. 5, regions pooled). However, their depths-at-capture cannot be meaningfully compared, as nearly all of the catches were made at one region. Age-1+ opakapaka occurred only in mid-depth trawls, and some age-0+ opakapaka were caught in deep trawls but were also frequently encountered in mid-depth trawls.

### Power Tests

One might question whether a bottom trawl is an adequate sampler for estimating distribution and abundance of juvenile



opakapaka in the MHI. Our power analysis estimated that nearly 100 trawls, an unacceptably large number, would be necessary to detect a 50% change in juvenile opakapaka catches at  $\alpha_2 = 0.05$  and a power = 0.8. For nonstatistical reasons, an upper limit of an "acceptable" number of trawls was set at 20. This upper limit was defined partly by the feasible effort and duration of trawling aboard the *Townsend Cromwell* (six to seven trawls per day for 3 days) and partly by a desire to limit habitat damage resulting from trawling activities. Additional power tests to detect a 50% change in catch were calculated for each of the three most frequently encountered species (*Trachinocephalus myops*, *Lagocephalus hypselogeneion*, and *Engyprosopon xenandrus*). Sufficient power ( $\geq 0.8$ ) for  $\leq 20$  trawls was indicated for only 3 of the 36 possible species-region combinations (species by region with depths pooled). Data for *E. xenandrus* had no power of resolution, *T. myops* had two instances of adequate power ( $N = 9$ , 10 trawls), and *L. hypselogeneion* had one instance ( $N = 9$ ). In general, a 50% change in the mean CPUE would likely go undetected for any of the major species sampled by bottom trawls.

In conclusion, bottom trawls do not promise to be an efficient sampling method for the detection of changes in the abundance of small benthic fishes at 61-91 m depths off the MHI. We are presently exploring alternative methods to characterize the depth-distribution range and habitat type of juvenile opakapaka.

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Table 1.--Boundaries of the 11 regions trawled during the  
*Townsend Cromwell* cruise TC-90-10.

| Region <sup>a</sup> | Trawl area bounded by |                     |
|---------------------|-----------------------|---------------------|
|                     | Latitude (N)          | Longitude (W)       |
| Haleiwa             | 21°36.4'-21°42.0'     | 158°04.0'-158°11.7' |
| Kaneohe Bay         | 21°30.8'-21°33.9'     | 157°47.6'-157°49.1' |
| Laie                | 21°38.8'-21°41.9'     | 157°53.0'-157°55.0' |
| NW Molokai          | 21°11.7'-21°12.5'     | 157°03.0'-157°05.7' |
| NE Penguin Bank     | 21°06.7'-21°09.7'     | 157°19.8'-157°24.0' |
| SE Penguin Bank     | 21°02.9'-21°04.3'     | 157°11.6'-157°18.1' |
| South Molokai       | 21°00.1'-21°02.8'     | 156°56.0'-157°01.1' |
| Kahului, Maui       | 20°57.1'-20°59.0'     | 156°24.7'-156°28.6' |
| Auau Channel        | 20°44.1'-20°49.4'     | 156°42.2'-156°47.3' |
| South Lanai         | 20°42.8'-20°43.3'     | 156°53.3'-156°55.0' |
| Lahilahi Pt.        | 21°26.9'-21°30.1'     | 158°13.3'-158°14.6' |

<sup>a</sup>Listed in order of cruise track.



Table 2.--Total catch and catch per unit effort, by depth and region, from Townsend Cromwell cruise 90-10 in the main Hawaiian Islands, 1990. Data are from nighttime quantitative trawls only; catches from several series of daytime and nighttime trawls are excluded. Weight (Wt) is expressed as 0.01 kg.

| Region                  | Depth zone | No.<br>trawls | Total catch |       | Mean•trawl <sup>-1</sup> |       |
|-------------------------|------------|---------------|-------------|-------|--------------------------|-------|
|                         |            |               | No.         | Wt.   | No.                      | Wt.   |
| Auau Channel            | Mid-depth  | 3             | 51          | 2.13  | 17                       | 0.71  |
|                         | Combined   | 3             | 51          | 2.13  | 17                       | 0.71  |
| Haleiwa, Oahu           | Mid-depth  | 3             | 50          | 1.51  | 17                       | 0.50  |
|                         | Deep       | 3             | 200         | 5.13  | 67                       | 1.71  |
|                         | Combined   | 6             | 250         | 6.64  | 42                       | 1.11  |
| Kahului, Maui           | Mid-depth  | 3             | 74          | 2.04  | 25                       | 0.68  |
|                         | Deep       | 3             | 59          | 0.94  | 20                       | 0.31  |
|                         | Combined   | 6             | 133         | 2.98  | 22                       | 0.50  |
| Kaneohe Bay,<br>Oahu    | Mid-depth  | 3             | 748         | 43.92 | 249                      | 14.64 |
|                         | Deep       | 2             | 373         | 14.43 | 187                      | 7.21  |
|                         | Combined   | 5             | 1121        | 58.35 | 224                      | 11.67 |
| Lahilahi Point,<br>Oahu | Mid-depth  | 3             | 10          | 0.05  | 3                        | 0.02  |
|                         | Deep       | 1             | 3           | 0.01  | 3                        | 0.01  |
|                         | Combined   | 4             | 13          | 0.06  | 3                        | 0.02  |
| Laie, Oahu              | Shallow    | 2             | 148         | 9.94  | 74                       | 4.97  |
|                         | Mid-depth  | 2             | 597         | 42.21 | 299                      | 21.10 |
|                         | Deep       | 2             | 146         | 9.13  | 73                       | 4.57  |
|                         | Combined   | 6             | 891         | 61.28 | 149                      | 10.21 |
| NE Penguin Bank         | Shallow    | 2             | 20          | 0.03  | 10                       | 0.02  |
|                         | Mid-depth  | 2             | 26          | 0.65  | 13                       | 0.33  |
|                         | Deep       | 1             | 9           | 0.14  | 9                        | 0.14  |
|                         | Combined   | 5             | 55          | 0.82  | 11                       | 0.16  |
| NW Molokai              | Shallow    | 2             | 23          | 0.95  | 12                       | 0.47  |
|                         | Mid-depth  | 2             | 50          | 2.77  | 25                       | 1.38  |
|                         | Deep       | 2             | 47          | 1.44  | 24                       | 0.72  |
|                         | Combined   | 6             | 120         | 5.16  | 20                       | 0.86  |
| SE Penguin Bank         | Mid-depth  | 4             | 24          | 1.55  | 6                        | 0.39  |
|                         | Deep       | 2             | 18          | 0.94  | 9                        | 0.47  |
|                         | Combined   | 6             | 42          | 2.49  | 7                        | 0.42  |
| South Lanai             | Deep       | 3             | 52          | 1.98  | 17                       | 0.66  |
|                         | Combined   | 3             | 52          | 1.98  | 17                       | 0.66  |

Table 2.--Continued.

| Region                | Depth zone | No.<br>trawls | Total catch |        | Mean·trawl <sup>-1</sup> |      |
|-----------------------|------------|---------------|-------------|--------|--------------------------|------|
|                       |            |               | No.         | Wt.    | No.                      | Wt.  |
| South Molokai         | Mid-depth  | 3             | 62          | 0.57   | 21                       | 0.19 |
|                       | Deep       | 3             | 57          | 1.65   | 19                       | 0.55 |
|                       | Combined   | 6             | 119         | 2.22   | 20                       | 0.37 |
| All regions<br>pooled | Shallow    | 6             | 191         | 10.92  | 32                       | 1.82 |
|                       | Mid-depth  | 28            | 1692        | 97.40  | 60                       | 3.48 |
|                       | Deep       | 22            | 964         | 35.79  | 44                       | 1.63 |
|                       | Combined   | 56            | 2847        | 144.11 | 51                       | 2.57 |



Table 3.--Absolute and ranked trawl catches, by depth, for each species present in night quantitative trawls (56 trawls) during the Townsend Cromwell cruise TC-90-10. Species listed according to their total rank in Appendix E. *Benthoosema fibulatum*, *Decapterus macarellus*, *Astronesthes* sp. are excluded. Deep = 91 m, mid-depth = 76 m, shallow = 61 m; R = rank, N = number of individuals captured.

| Species                            | Depth zone |      |     |      |         |      |
|------------------------------------|------------|------|-----|------|---------|------|
|                                    | Deep       |      | Mid |      | Shallow |      |
|                                    | N          | R    | N   | R    | N       | R    |
| <i>Lagocephalus hypselogeneion</i> | 233        | 2.0  | 555 | 1.0  | 57      | 2.0  |
| <i>Trachinocephalus myops</i>      | 256        | 1.0  | 368 | 2.0  | 45      | 3.0  |
| <i>Engyprosopon xenandrus</i>      | 137        | 3.0  | 76  | 6.0  | 1       | 12.0 |
| <i>Lutjanus kasmira</i>            | 6          | 19.0 | 147 | 3.0  | 0       | -    |
| <i>Pristipomoides filamentosus</i> | 10         | 12.5 | 113 | 4.0  | 0       | -    |
| <i>Synagrops argyrea</i>           | 94         | 4.0  | 23  | 9.0  | 0       | -    |
| <i>Heniochus diphreutes</i>        | 6          | 19.0 | 99  | 5.0  | 1       | 12.0 |
| <i>Ariosoma bowersi</i>            | 19         | 6.0  | 39  | 7.5  | 1       | 12.0 |
| <i>Bleekeria gilli</i>             | 0          | -    | 0   | -    | 64      | 1.0  |
| <i>Dactyloptena orientalis</i>     | 14         | 7.0  | 39  | 7.5  | 0       | -    |
| <i>Parupeneus chrysonemus</i>      | 23         | 5.0  | 22  | 10.5 | 0       | -    |
| <i>Bothus thompsoni</i>            | 5          | 22.5 | 22  | 10.5 | 7       | 4.0  |
| <i>Synodus falcatus</i>            | 9          | 14.5 | 10  | 15.0 | 0       | -    |
| <i>Lactoria</i> spp.               | 6          | 19.0 | 17  | 12.0 | 2       | 7.0  |
| <i>Gnatholepis anjerensis</i>      | 13         | 8.0  | 8   | 20.0 | 0       | -    |
| <i>Priacanthus alalaua</i>         | 5          | 22.5 | 15  | 13.0 | 0       | -    |
| <i>Iracundus signifer</i>          | 4          | 26.0 | 3   | 30.0 | 0       | -    |
| <i>Canthigaster rivulatus</i>      | 10         | 17.0 | 7   | 21.0 | 1       | 12.0 |
| Bothidae (unidentified sp.)        | 9          | 14.5 | 9   | 17.5 | 0       | -    |
| <i>Bothus pantherinus</i>          | 1          | 45.0 | 13  | 14.0 | 1       | 12.0 |
| <i>Chromis leucura</i>             | 12         | 9.5  | 5   | 23.5 | 0       | -    |
| <i>Callionymus decoratus</i>       | 4          | 26.0 | 9   | 17.5 | 0       | -    |
| <i>Parapercis schauinsland</i>     | 4          | 26.0 | 3   | 30.0 | 4       | 5.0  |
| <i>Mulloides auriflamma</i>        | 1          | 45.0 | 6   | 22.0 | 0       | -    |
| <i>Fistularia petimba</i>          | 11         | 11.0 | 3   | 30.0 | 0       | -    |
| <i>Ophidion muraenolepis</i>       | 12         | 9.5  | 0   | -    | 0       | -    |

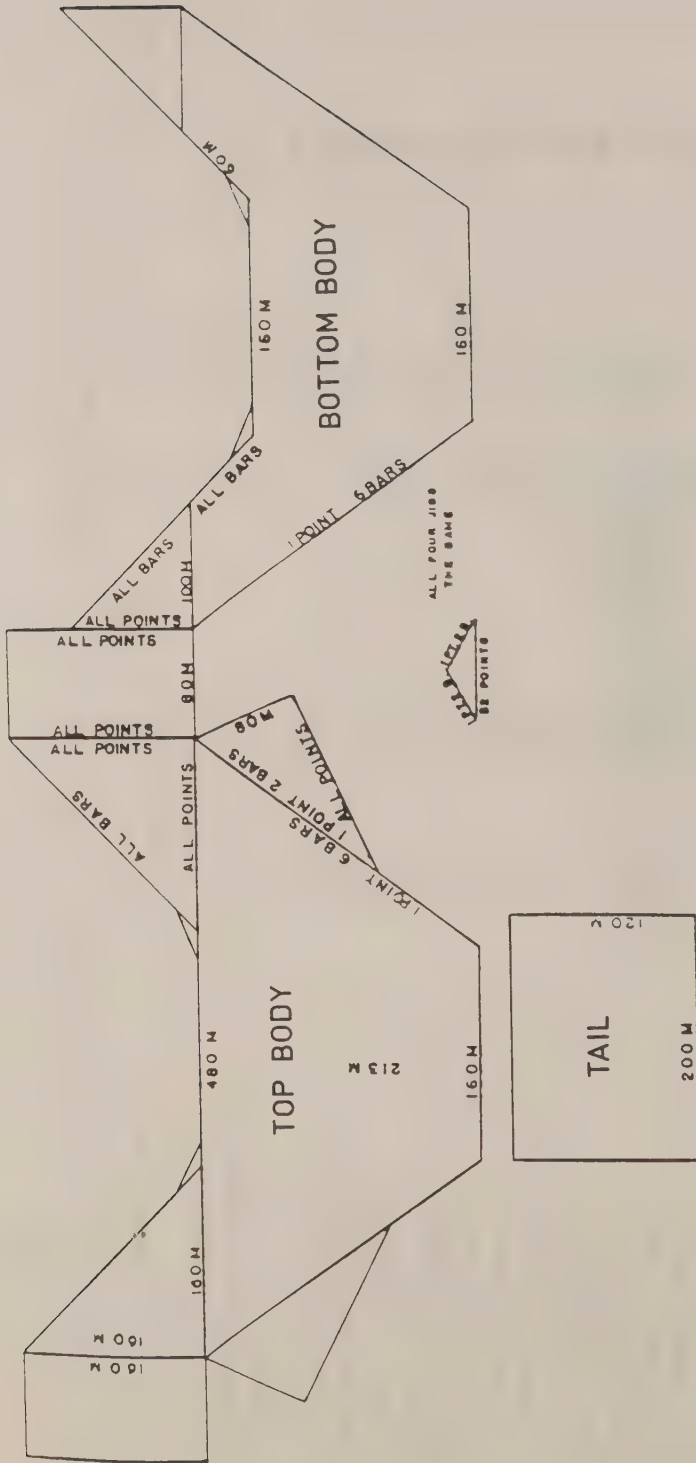
Table 3.--Continued.

| Species                          | Depth zone |      |     |      |         |      |
|----------------------------------|------------|------|-----|------|---------|------|
|                                  | Deep       |      | Mid |      | Shallow |      |
|                                  | N          | R    | N   | R    | N       | R    |
| <i>Parupeneus pleurostigma</i>   | 1          | 45.0 | 9   | 17.5 | 0       | -    |
| Synodontidae (unidentified sp.)  | 8          | 16.0 | 5   | 23.5 | 0       | -    |
| <i>Canthigaster epilampra</i>    | 7          | 17.0 | 3   | 30.0 | 0       | -    |
| <i>Scorpaena colorata</i>        | 3          | 30.0 | 3   | 30.0 | 3       | 6.0  |
| <i>Mulloides flavolineatus</i>   | 0          | -    | 9   | 17.5 | 1       | 12.0 |
| <i>Chaetodon miliaris</i>        | 5          | 22.5 | 4   | 25.0 | 0       | -    |
| <i>Saurenhelys</i> sp.           | 2          | 34.5 | 2   | 39.0 | 0       | -    |
| <i>Chromis verater</i>           | 5          | 22.5 | 0   | -    | 0       | -    |
| <i>Halieutaea retifera</i>       | 3          | 30.0 | 2   | 39.0 | 0       | -    |
| <i>Myripristis chryseres</i>     | 0          | -    | 2   | 39.0 | 0       | -    |
| <i>Apogon maculiferus</i>        | 2          | 34.5 | 2   | 39.0 | 0       | -    |
| <i>Antennarius striatus</i>      | 1          | 45.0 | 3   | 30.0 | 0       | -    |
| <i>Canthigaster coronatus</i>    | 1          | 45.0 | 2   | 39.0 | 0       | -    |
| Apogonidae (unidentified sp.)    | 0          | -    | 3   | 30.0 | 0       | -    |
| <i>Carapis homei</i>             | 0          | -    | 2   | 39.0 | 0       | -    |
| <i>Dasyatis</i> sp.              | 3          | 30.0 | 0   | -    | 0       | -    |
| Nomeidae (unidentified sp.)      | 3          | 30.0 | 0   | -    | 0       | -    |
| <i>Eurypegasus papilio</i>       | 2          | 34.5 | 1   | 52.0 | 0       | -    |
| <i>Scorpaenopsis altirostris</i> | 0          | -    | 3   | 30.0 | 0       | -    |
| <i>Scorpaenopsis brevifrons</i>  | 0          | -    | 3   | 30.0 | 0       | -    |
| <i>Oxycirrhites typus</i>        | 3          | 30.0 | 0   | -    | 0       | -    |
| <i>Anthias thompsoni</i>         | 1          | 45.0 | 1   | 52.0 | 0       | -    |
| <i>Upeneus arge</i>              | 0          | -    | 2   | 39.0 | 0       | -    |
| <i>Apogon snyderi</i>            | 0          | -    | 2   | 39.0 | 0       | -    |
| <i>Centropyge potteri</i>        | 2          | 34.5 | 0   | -    | 0       | -    |
| <i>Hippocampus kuda</i>          | 1          | 45.0 | 1   | 52.0 | 0       | -    |
| <i>Sphyaena japonicus</i>        | 0          | -    | 0   | -    | 0       | -    |
| <i>Synodus ulae</i>              | 0          | -    | 2   | 39.0 | 0       | -    |
| <i>Taenianotus triacanthus</i>   | 1          | 45.0 | 0   | -    | 0       | -    |
| <i>Antigonia eos</i>             | 1          | 45.0 | 0   | -    | 0       | -    |



Table 3.---Continued

| Species                                | Depth zone |      |     |      |         |      |
|----------------------------------------|------------|------|-----|------|---------|------|
|                                        | Deep       |      | Mid |      | Shallow |      |
|                                        | N          | R    | N   | R    | N       | R    |
| <i>Amanses (Cantherines) sp.</i>       | 0          | -    | 1   | 52.0 | 0       | -    |
| <i>Apterichtus flavicaudus</i>         | 0          | -    | 0   | -    | 0       | -    |
| <i>Sammarsiscus corallinus</i>         | 0          | -    | 1   | 52.0 | 0       | -    |
| <i>Brotula multibarbata</i>            | 0          | -    | 1   | 52.0 | 0       | -    |
| <i>Centropyge fisheri</i>              | 0          | -    | 1   | 52.0 | 0       | -    |
| <i>Cheilinus bimaculatus</i>           | 0          | -    | 0   | -    | 0       | -    |
| <i>Congrina aequorea</i>               | 0          | -    | 1   | 52.0 | 0       | -    |
| <i>Dendrochirus barberi</i>            | 1          | 45.0 | 0   | -    | 0       | -    |
| <i>Diodon hystrix</i>                  | 0          | -    | 1   | 52.0 | 0       | -    |
| <i>Epigonus fragilis</i>               | 0          | -    | 1   | 52.0 | 0       | -    |
| <i>Festucalex erythraeus</i>           | 1          | 45.0 | 0   | -    | 0       | -    |
| <i>Foa brachygramma</i>                | 0          | -    | 1   | 52.0 | 0       | -    |
| <i>Chaetodon fremblii</i>              | 1          | 45.0 | 0   | -    | 0       | -    |
| <i>Gempylidae (unidentified sp.)</i>   | 0          | -    | 1   | 52.0 | 0       | -    |
| <i>Cirrhilabrus jordani</i>            | 1          | 45.0 | 0   | -    | 0       | -    |
| <i>Carcharhinus milberti</i>           | 0          | -    | 0   | -    | 1       | 12.0 |
| <i>Neomerinthe rufescens</i>           | 0          | -    | 1   | 52.0 | 0       | -    |
| <i>Ophichthidae (unidentified sp.)</i> | 1          | 45.0 | 0   | -    | 0       | -    |
| <i>Physiculus sp.</i>                  | 1          | 45.0 | 0   | -    | 0       | -    |
| <i>Cirruraena playfairii</i>           | 1          | 45.0 | 0   | -    | 0       | -    |
| <i>Pseudojuloides cerasinus</i>        | 0          | -    | 0   | -    | 0       | -    |
| <i>Psilogobius mainlandi</i>           | 0          | -    | 0   | -    | 0       | -    |
| <i>Pseudanthias winniensis</i>         | 1          | 45.0 | 1   | 52.0 | 0       | -    |
| <i>Synodus amaranthus</i>              | 0          | -    | 1   | 52.0 | 0       | -    |
| <i>Sargocentron xantherythrum</i>      | 0          | -    | 1   | 52.0 | 0       | -    |
| <i>Pristipomoides sieboldii</i>        | 0          | -    | 1   | 52.0 | 0       | -    |
| <i>Synodus usitatus</i>                | 0          | -    | 0   | -    | 1       | 12.0 |
| <i>Gymnothorax flavomarginatus</i>     | 0          | -    | 0   | -    | 0       | -    |
| <i>Gymnothorax mucifer</i>             | 0          | -    | 0   | -    | 0       | -    |



BODY, WINGS, DOGEARS, AND JIBS ARE 18-THREAD, 2 1/2" STRETCH COTTON WEBBING.

TAIL IS 42-THREAD, 2 1/2" STRETCH COTTON WEBBING

Figure 1.--A 74-ft (22.6-m) balloon trawl used on the merchant vessel Oregon (from fig. 10, U.S. Fish and Wildlife Service 1951).



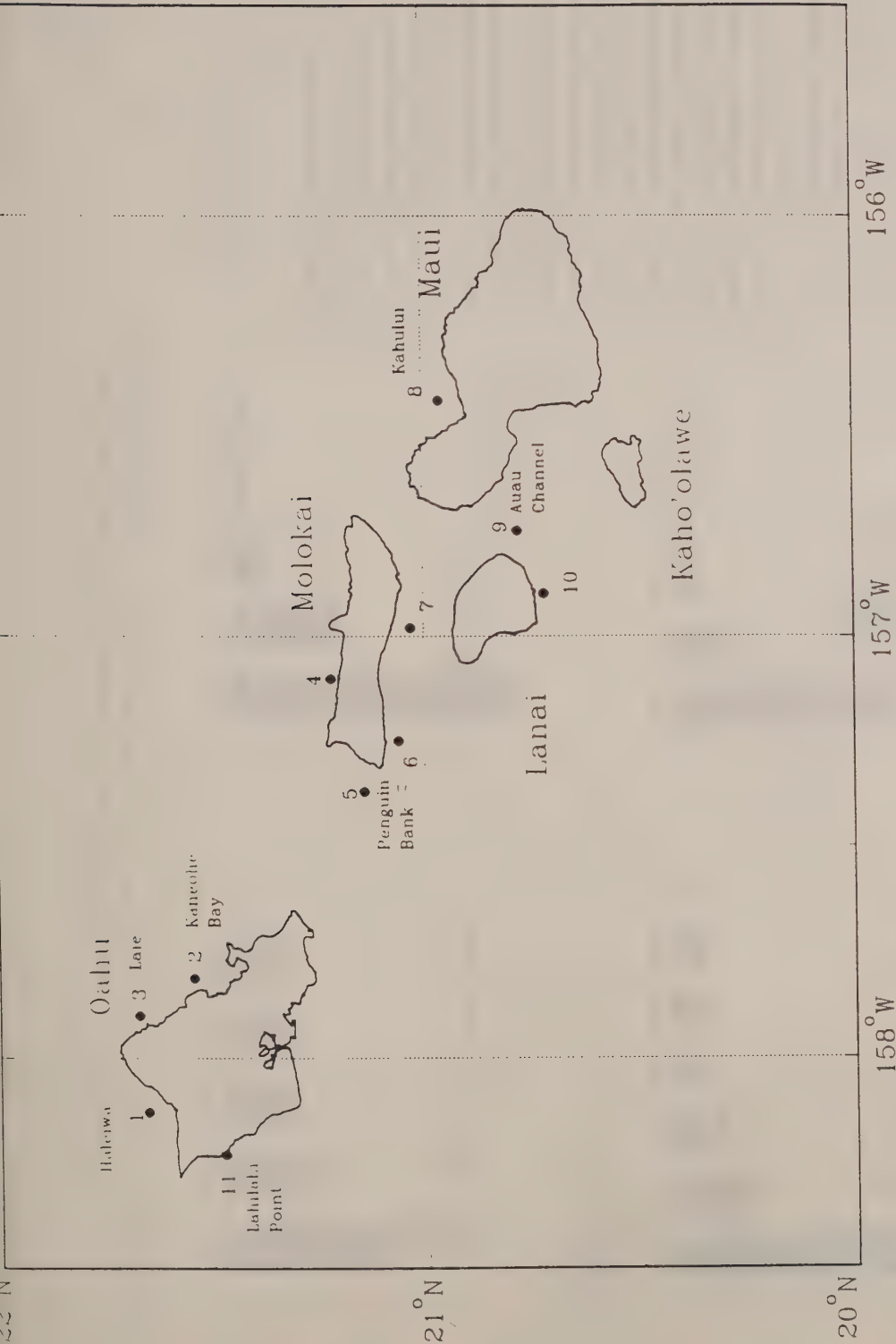


Figure 2.--Regions trawled by the Townsend Cromwell during cruise TC-90-10. See Table 1 for latitude and longitude positions for each region. (Latitude and longitude coordinates for this map are from the Hawaiian Island Mapping Program.)

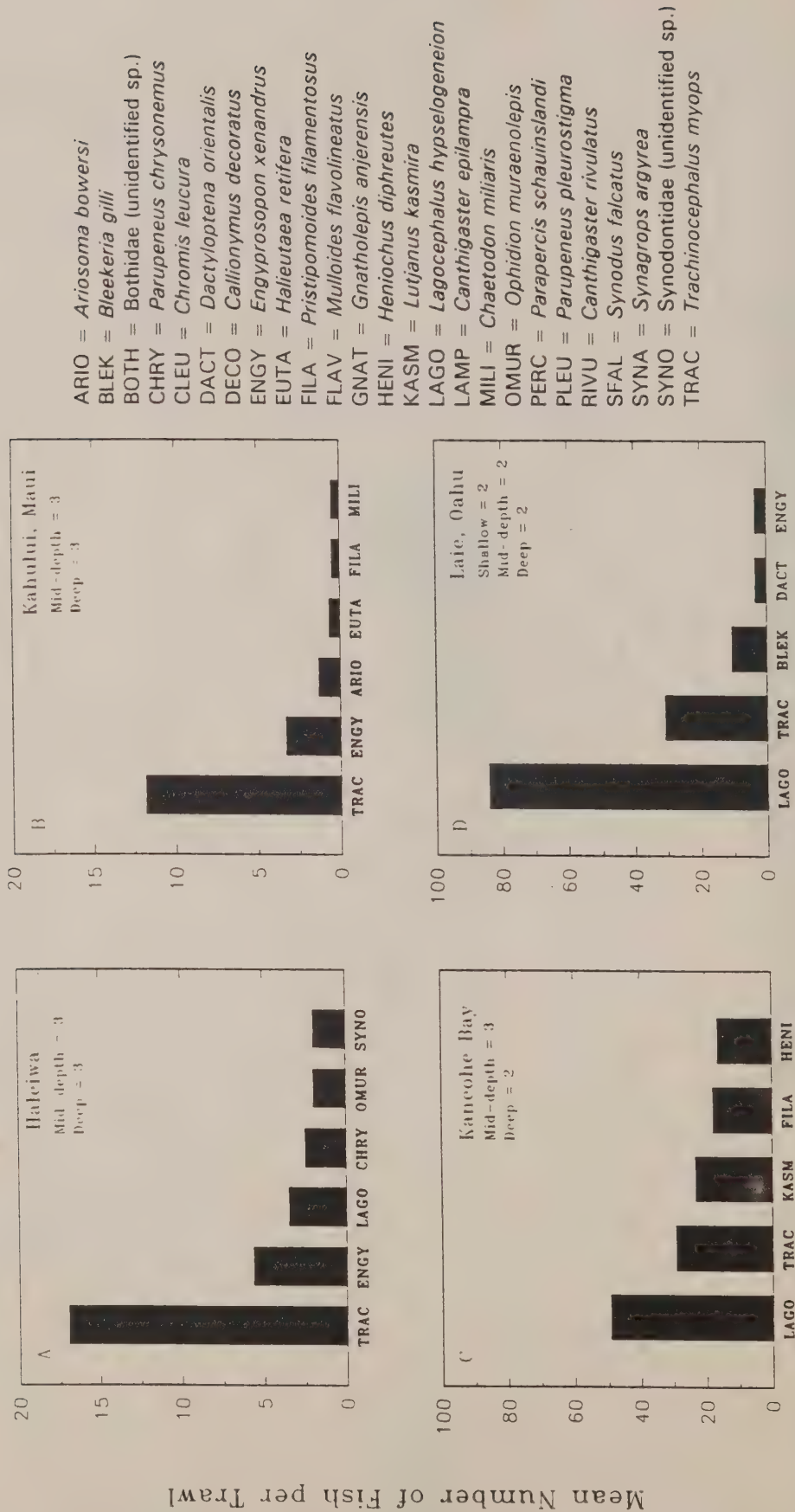


Figure 3.--(A-H). Mean number of fish per trawl for top-ranked species in eight regions. Number of trawls per depth are listed for each area.

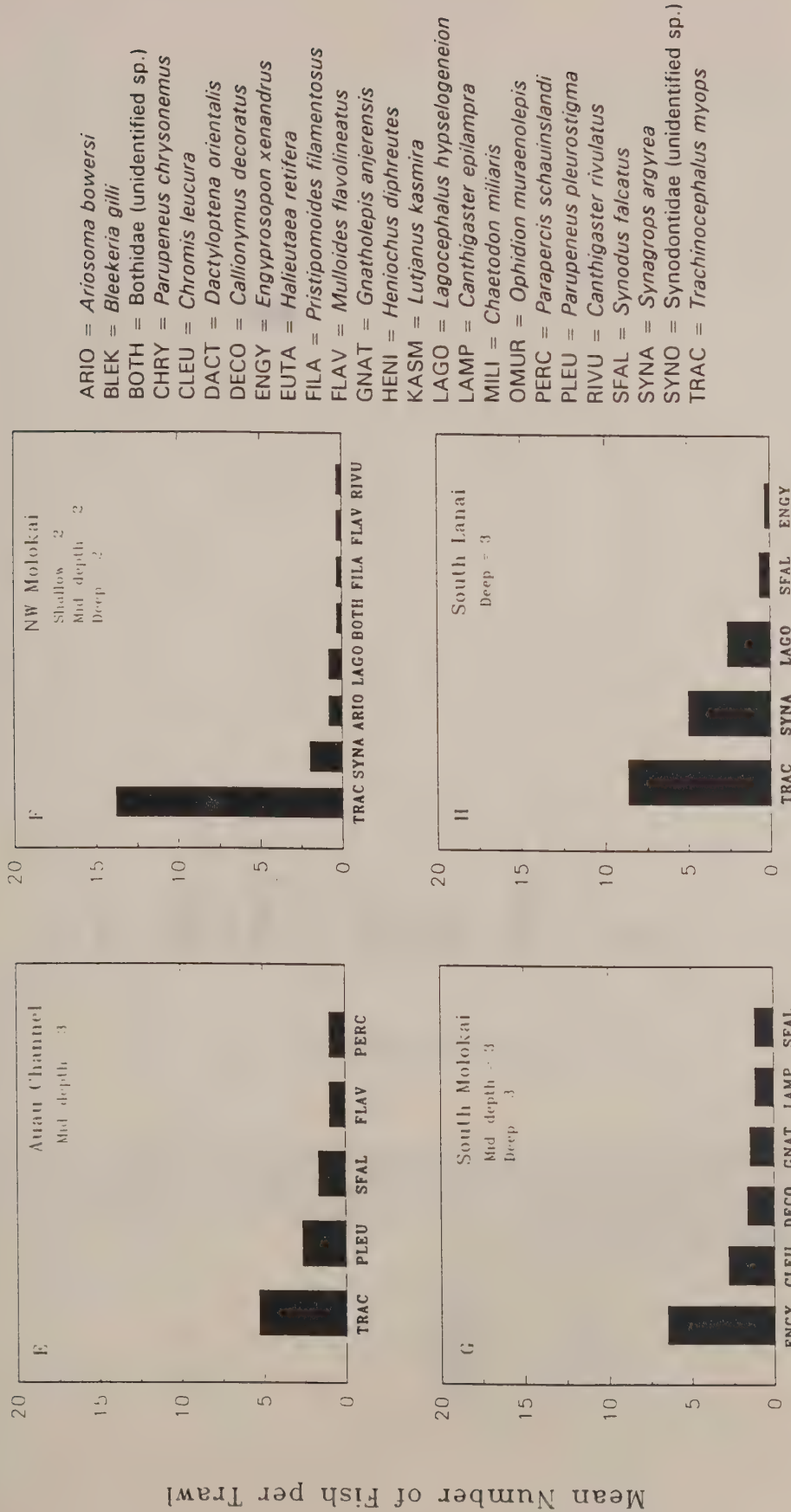


Figure 3.--Continued.



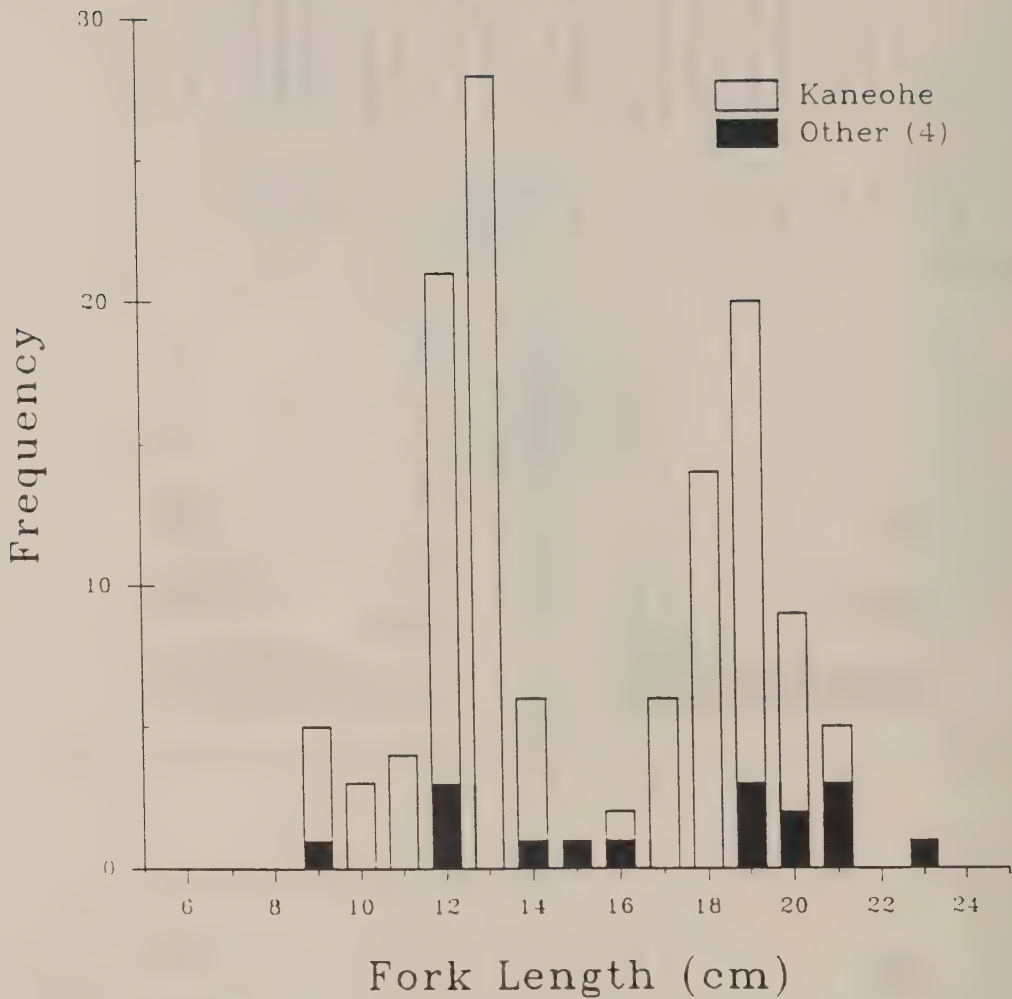


Figure 4.--Length-frequency distribution for opakapaka, *Pristipomoides filamentosus*, caught at Kaneohe Bay and four other regions. Fork length was rounded to the nearest centimeter.

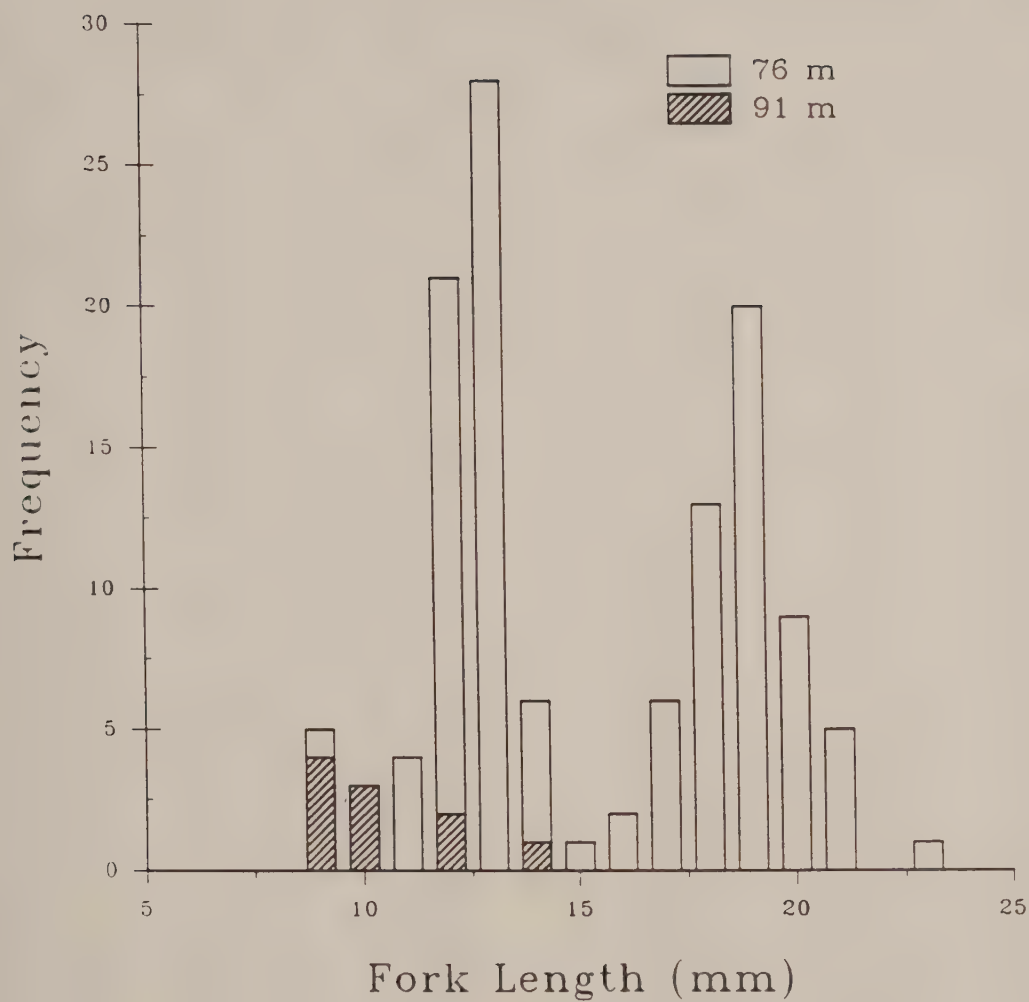


Figure 5.--Length-frequency distribution for opakapaka, *Pristipomoides filamentosus*, by depth of capture (with regions combined).

Appendix A.--Dates, depths, and positions of the 80 bottom trawling stations during *Townsend Cromwell* cruise 90-10 in the main Hawaiian Islands.

| Date               | Station No.      | Depth (m) |      | Midpoint     |               |
|--------------------|------------------|-----------|------|--------------|---------------|
|                    |                  | Range     | Mean | Latitude (N) | Longitude (W) |
| 11/29              | 13 <sup>a</sup>  | 84-91     | 88   | 21°38.4'     | 158°07.2'     |
| 11/29              | 14 <sup>a</sup>  | - -       | --   | 21°41.0'     | 158°05.0'     |
| 11/29              | 15               | 77-93     | 90   | 21°41.4'     | 158°05.0'     |
| 11/29              | 16               | 77-97     | 90   | 21°40.2'     | 158°06.0'     |
| 11/30              | 20               | 62-71     | 68   | 21°38.9'     | 158°06.8'     |
| 11/30              | 21               | 68-80     | 75   | 21°36.6'     | 158°09.0'     |
| 11/30              | 22               | 71-82     | 77   | 21°36.4'     | 158°11.7'     |
| 11/30              | 23               | 79-84     | 90   | 21°39.8'     | 158°06.2'     |
| 11/30              | 45               | 71-93     | 80   | 21°32.4'     | 157°48.1'     |
| 11/30              | 46               | 79-91     | 88   | 21°33.8'     | 157°48.0'     |
| 11/30              | 50               | 71-79     | 77   | 21°33.0'     | 157°47.8'     |
| 12/01              | 51 <sup>a</sup>  | 60-66     | 64   | 21°30.8'     | 157°47.8'     |
| 12/01              | 52 <sup>a</sup>  | 80-181+   | --   | 21°31.2'     | 157°47.6'     |
| 12/01              | 56               | 73-77     | 75   | 21°33.8'     | 157°49.1'     |
| 12/01              | 57               | 84-91     | 88   | 21°33.9'     | 157°48.8'     |
| 12/01              | 79               | 70-77     | 73   | 21°41.3'     | 157°54.3'     |
| 12/01              | 80               | 73-77     | 75   | 21°39.8'     | 157°53.8'     |
| 12/02              | 84               | 77-88     | 84   | 21°40.7'     | 157°53.6'     |
| 12/02              | 85               | 86-95     | 88   | 21°39.8'     | 157°53.4'     |
| 12/02              | 101 <sup>a</sup> | 51-62     | 57   | 21°39.6'     | 157°54.0'     |
| 12/02              | 102              | 51-59     | 55   | 21°41.0'     | 157°54.6'     |
| 12/02              | 103              | 53-59     | 57   | 21°40.6'     | 157°54.7'     |
| 12/02              | 104 <sup>a</sup> | 49-64     | 60   | 21°30.0'     | 157°46.8'     |
| 12/03              | 122              | 57-64     | 60   | 21°12.0'     | 157°04.8'     |
| 12/03              | 123              | 84-91     | 88   | 21°11.8'     | 157°04.8'     |
| 12/03              | 127              | 55-60     | 57   | 21°12.2'     | 157°04.6'     |
| 12/03              | 128              | 86-91     | 90   | 21°12.2'     | 157°04.0'     |
| 12/03              | 129              | 73-79     | 75   | 21°12.3'     | 157°04.7'     |
| 12/04              | 133              | 75-90     | 80   | 21°12.2'     | 157°03.7'     |
| 12/04              | 150 <sup>a</sup> | 88-97     | 91   | 21°09.3'     | 157°21.2'     |
| 12/04              | 151              | 86-91     | 88   | 21°09.2'     | 157°21.6'     |
| 12/04 <sup>*</sup> | 155              | 53-59     | 55   | 21°08.0'     | 157°20.5'     |
| 12/04              | 156              | 53-60     | 59   | 21°08.3'     | 157°20.6'     |
| 12/05              | 160              | 68-82     | 80   | 21°09.2'     | 157°20.5'     |
| 12/05              | 161              | 62-77     | 75   | 21°07.4'     | 157°23.3'     |
| 12/05              | 172              | 66-75     | 70   | 21°02.9'     | 157°16.3'     |
| 12/05              | 173              | 82-101    | 91   | 21°03.6'     | 157°13.1'     |
| 12/05              | 177              | 84-97     | 88   | 21°03.2'     | 157°14.4'     |
| 12/05              | 178              | 66-77     | 73   | 21°02.9'     | 157°17.3'     |
| 12/06              | 182              | 60-82     | 75   | 21°04.1'     | 157°12.5'     |
| 12/06              | 183              | 53-86     | 71   | 21°04.1'     | 157°14.6'     |
| 12/06              | 203              | 70-84     | 79   | 21°02.6'     | 156°59.6'     |



## Appendix A.--Continued.

| Date  | Station<br>No.   | Depth (m) |      | Midpoint        |                  |
|-------|------------------|-----------|------|-----------------|------------------|
|       |                  | Range     | Mean | Latitude<br>(N) | Longitude<br>(W) |
| 12/06 | 204              | 70-79     | 75   | 21°02.8'        | 156°59.9'        |
| 12/06 | 208              | 60-77     | 70   | 21°01.8'        | 156°58.7'        |
| 12/06 | 209              | 82-90     | 86   | 21°02.0'        | 156°59.0'        |
| 12/07 | 213              | 79-97     | 90   | 21°01.1'        | 156°57.5'        |
| 12/07 | 214              | 66-99     | 82   | 21°00.5'        | 156°56.7'        |
| 12/07 | 235              | 84-88     | 86   | 20°58.3'        | 156°25.7'        |
| 12/07 | 236              | 91-95     | 93   | 20°58.1'        | 156°27.1'        |
| 12/07 | 240              | 70-79     | 77   | 20°57.2'        | 156°27.2'        |
| 12/07 | 241              | 70-75     | 73   | 20°57.2'        | 156°27.4'        |
| 12/08 | 245              | 71-79     | 77   | 20°57.5'        | 156°27.6'        |
| 12/08 | 246              | 84-90     | 88   | 20°58.1'        | 156°27.8'        |
| 12/09 | 267              | 62-77     | 66   | 20°46.8'        | 156°46.1'        |
| 12/09 | 268              | 68-80     | 71   | 20°47.5'        | 156°44.9'        |
| 12/09 | 269              | 68-93     | 73   | 20°47.5'        | 156°44.9'        |
| 12/10 | 270              | 93-99     | 95   | 20°43.1'        | 156°55.1'        |
| 12/10 | 271              | 82-90     | 88   | 20°43.2'        | 156°54.3'        |
| 12/10 | 272              | 86-95     | 90   | 20°43.1'        | 156°54.8'        |
| 12/10 | 273              | 55-59     | 55   | 21°03.8'        | 157°17.5'        |
| 12/10 | 274              | 49-57     | 53   | 21°03.9'        | 157°17.6'        |
| 12/10 | 275              | 64-66     | 64   | 21°03.1'        | 157°19.4'        |
| 12/10 | 276              | 84-91     | 88   | 21°02.6'        | 157°16.4'        |
| 12/10 | 277              | 84-91     | 90   | 21°02.6'        | 157°17.2'        |
| 12/10 | 278              | 70-77     | 75   | 21°03.1'        | 157°14.6'        |
| 12/10 | 279              | 68-77     | 71   | 21°03.1'        | 157°17.6'        |
| 12/10 | 280              | 57-60     | 59   | 21°03.9'        | 157°17.0'        |
| 12/10 | 281              | 55-59     | 57   | 21°03.8'        | 157°15.8'        |
| 12/11 | 282              | 73-82     | 77   | 21°27.5'        | 158°13.5'        |
| 12/11 | 283              | 86-110    | 99   | 21°27.4'        | 158°13.4'        |
| 12/11 | 284              | 70-88     | 77   | 21°28.0'        | 158°13.7'        |
| 12/11 | 285              | 70-86     | 73   | 21°28.4'        | 158°14.3'        |
| 12/12 | 286              | 84-90     | 88   | 21°38.7'        | 158°07.1'        |
| 12/12 | 287              | 86-93     | 90   | 21°39.1'        | 158°06.8'        |
| 12/12 | 288              | 71-75     | 73   | 21°36.9'        | 158°08.9'        |
| 12/12 | 289              | 70-73     | 71   | 21°38.3'        | 158°06.6'        |
| 12/12 | 290              | 44-60     | 53   | 21°38.9'        | 158°05.4'        |
| 12/12 | 291 <sup>a</sup> | 49-64     | 62   | 21°39.9'        | 158°05.6'        |
| 12/12 | 292              | 49-64     | 60   | 21°38.7'        | 158°06.1'        |
| 12/12 | 293              | 53-64     | 60   | 21°38.9'        | 158°05.8'        |

<sup>a</sup>Non-quantitative sample.

Appendix B.--Speed, duration, and distance of trawl for  
the 80 bottom trawling stations sampled  
during the *Townsend Cromwell* cruise 90-10  
in the main Hawaiian Islands.

| Station<br>No.   | Duration<br>(min) | Speed<br>(m/s) | Trawl<br>distance<br>(km) |
|------------------|-------------------|----------------|---------------------------|
| 13 <sup>a</sup>  | 31                | 1.32           | 2.46                      |
| 14 <sup>a</sup>  | 39                | 1.32           | 3.09                      |
| 15               | 32                | 1.32           | 2.53                      |
| 16               | 32                | 1.32           | 2.53                      |
| 20               | 31                | 1.32           | 2.46                      |
| 21               | 30                | 1.32           | 2.38                      |
| 22               | 32                | 1.32           | 2.53                      |
| 23               | 32                | 1.32           | 2.53                      |
| 45               | 31                | 1.32           | 2.46                      |
| 46               | 32                | 1.32           | 2.53                      |
| 50               | 31                | 1.32           | 2.46                      |
| 51 <sup>a</sup>  | 13                | 1.32           | 1.03                      |
| 52 <sup>a</sup>  | 30                | 1.32           | 2.38                      |
| 56               | 31                | 1.32           | 2.46                      |
| 57               | 30                | 1.32           | 2.38                      |
| 79               | 31                | 1.32           | 2.46                      |
| 80               | 28                | 1.32           | 2.22                      |
| 84               | 31                | 1.32           | 2.46                      |
| 85               | 32                | 1.32           | 2.53                      |
| 101 <sup>a</sup> | 29                | 2.10           | 3.65                      |
| 102              | 33                | 1.53           | 3.03                      |
| 103              | 31                | 1.68           | 3.12                      |
| 104 <sup>a</sup> | 29                | 1.58           | 2.75                      |
| 122              | 19                | 2.10           | 2.39                      |
| 123              | 19                | 2.10           | 2.39                      |
| 127              | 19                | 1.63           | 1.86                      |
| 128              | 20                | 2.10           | 2.52                      |
| 129              | 20                | 2.21           | 2.65                      |
| 133              | 19                | 2.21           | 2.52                      |
| 150 <sup>a</sup> | 19                | 2.21           | 2.52                      |
| 151              | 18                | 2.37           | 2.56                      |
| 155              | 19                | 1.84           | 2.10                      |
| 156              | 19                | 2.00           | 2.28                      |
| 160              | 20                | 2.10           | 2.52                      |
| 161              | 18                | 2.63           | 2.84                      |
| 172              | 20                | 2.21           | 2.65                      |
| 173              | 21                | 2.26           | 2.85                      |
| 177              | 20                | 2.37           | 2.84                      |
| 178              | 19                | 2.47           | 2.82                      |
| 182              | 19                | 2.52           | 2.87                      |
| 183              | 19                | 2.10           | 2.39                      |

## Appendix B.--Continued.

| Station<br>No.   | Duration<br>(min) | Speed<br>(m/s) | Trawl<br>distance<br>(km) |
|------------------|-------------------|----------------|---------------------------|
| 203              | 19                | 2.37           | 2.70                      |
| 204              | 20                | 2.26           | 2.71                      |
| 208              | 21                | 2.10           | 2.65                      |
| 209              | 19                | 2.10           | 2.39                      |
| 213              | 21                | 2.37           | 2.99                      |
| 214              | 19                | 2.37           | 2.70                      |
| 235              | 19                | 2.21           | 2.52                      |
| 236              | 20                | 2.16           | 2.59                      |
| 240              | 19                | 2.37           | 2.70                      |
| 241              | 19                | 2.21           | 2.52                      |
| 245              | 18                | 2.21           | 2.39                      |
| 246              | 19                | 2.21           | 2.52                      |
| 267              | 15                | 2.16           | 1.94                      |
| 268              | 20                | 2.31           | 2.77                      |
| 269              | 12                | 2.42           | 1.74                      |
| 270              | 18                | 2.26           | 2.44                      |
| 271              | 20                | 2.26           | 2.71                      |
| 272              | 19                | 2.37           | 2.70                      |
| 273              | 19                | 1.84           | 2.10                      |
| 274              | 19                | 2.37           | 2.70                      |
| 275              | 20                | 2.52           | 3.02                      |
| 276              | 20                | 2.21           | 2.65                      |
| 277              | 20                | 2.16           | 2.59                      |
| 278              | 20                | 2.10           | 2.52                      |
| 279              | 20                | 2.26           | 2.71                      |
| 280              | 20                | 1.79           | 2.15                      |
| 281              | 19                | 1.74           | 1.98                      |
| 282              | 20                | 2.16           | 2.59                      |
| 283              | 15                | 2.21           | 1.99                      |
| 284              | 18                | 2.10           | 2.27                      |
| 285              | 19                | 1.95           | 2.22                      |
| 286              | 19                | 2.16           | 2.46                      |
| 287              | 18                | 2.21           | 2.39                      |
| 288              | 19                | 2.21           | 2.52                      |
| 289              | 19                | 2.05           | 2.34                      |
| 290              | 19                | 2.00           | 2.28                      |
| 291 <sup>a</sup> | 22                | 2.10           | 2.77                      |
| 292              | 25                | 1.58           | 2.37                      |
| 293              | 27                | 1.58           | 2.56                      |

<sup>a</sup>Non-quantitative sample



Appendix C.--Annotated bibliography of taxonomic keys used in identifying fishes caught during the *Townsend Cromwell* cruise TC-90-10--updated for current nomenclature (based on taxonomic review by Bruce Mundy, pers. commun.).

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Dawson, C. E.

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Re. Identification of *Dendrochirus barberi*, *Iracundus signifer*, *Neomerinthe rufescens*, *Scorpaena colorata*, *Scorpaenopsis altirostris*, *Scorpaenopsis brevifrons*, *Taenianotus triacanthus*.

Fricke, R.

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Re. Identification of *Callionymus decoratus*.

## Appendix C.--Continued.

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Hensley, D. A. and A. Y. Suzumoto.

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Re. Identification of *Bothus thompsoni*, *B. pantherinus*, and *Engyprosopon xenandrus*.

Mayer, G. F.

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McCosker, J. E.

1979. The snake eels (Pisces, Ophichthyidae) of the Hawaiian Islands, with the description of two new species. *Procs. Calif. Acad. Sci.* 42(2):57-67.

Re. Identification of *Cirrimuraena playfairii* and *Apterichtus flavicaudus*.

## Appendix C.--Continued.

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Appendix D.--The fish taxa (both teleosts and elasmobranchs; alphabetized within family) trawled on the *Townsend Cromwell* cruise TC-90-10 in the main Hawaiian Islands, 1990. There are 89 taxa present in 47 families; 83 of the taxa were identified to genus and 77 to species.

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**Ammodytidae***Bleekeria gilli***Antennariidae***Antennarius striatus***Apogonidae**

Unidentified sp.  
*Apogon maculiferus*  
*A. snyderi*  
*Epigonus fragilis*  
*Foa brachygramma*  
*Synagrops argyrea*

**Bothidae**

Unidentified sp.  
*Bothus pantherinus*  
*B. thompsoni*  
*Engyprosopon xenandrus*

**Brotulidae***Brotula multibarbata***Callionymidae***Callionymus decoratus***Canthigasteridae**

*Canthigaster coronatus*  
*C. epilampra*  
*C. rivulatus*

**Caproidae***Antigonia eos***Carangidae***Decapterus macarellus***Carapidae***Carapis homei***Carcharhinidae***Carcharhinus milberti***Chaetodontidae**

*Chaetodon fremblii*  
*C. miliaris*  
*Heniochus diphreutes*

**Cirrhitidae***Oxycirrhites typus***Congridae**

*Ariosoma bowersi*  
*Congrina aequorea*

**Dactylopteridae***Dactyloptena orientalis***Dasyatidae***Dasyatis* sp.**Diodontidae***Diodon hystrix***Fistulariidae***Fistularia petimba***Gempylidae**

Unidentified sp.

## Appendix D.--Continued.

**Gobiidae**

*Gnatholepis anjerensis*  
*Psilogobius mainlandi*

**Holocentridae**

*Myripristis chryseres*  
*Sargocentron*  
*xantherythrum*

**Labridae**

*Cheilinus bimaculatus*  
*Cirrilabrus jordani*  
*Pseudojuloides cerasinus*

**Lutjanidae**

*Lutjanus kasmira*  
*Pristipomoides*  
*filamentosus*  
*P. sieboldii*

**Monacanthidae**

*Amanses* sp.

**Moridae**

*Physiculus* sp.

**Mullidae**

*Mulloides auriflamma*  
*M. flavolineatus*  
*Parupeneus chrysonemus*  
*P. pleurostigma*  
*Upeneus arge*

**Muraenidae**

*Gymnothorax*  
*flavomarginatus*  
*G. mucifer*

**Myctophidae**

*Benthoosema fibulatum*

**Nettastiomatidae**

*Saurenehelys* sp.

**Nomeidae**

Unidentified sp.

**Ogcocephalidae**

*Halieutaea retifera*

**Ophichthyidae**

Unidentified sp.  
*Apterichtus flavicaudus*  
*Cirrimuraena playfairii*

**Ophidiidae**

*Ophidion muraenolepis*

**Ostraciontidae**

*Lactoria* spp.

**Parapercidae**

*Parapercis schauinslandi*

**Pegasidae**

*Eurypegasmus papilio*

**Pleuronectidae**

*Sammariscus corallinus*

**Pomacanthidae**

*Centropyge fisheri*  
*C. potteri*



Appendix D.--Continued.

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**Pomacentridae**

*Chromis leucura*  
*C. verater*

**Priacanthidae**

*Priacanthus alalaua*

**Scorpaenidae**

*Dendrochirus barberi*  
*Iracundus signifer*  
*Neomerinthe rufescens*  
*Scorpaena colorata*  
*Scorpaenopsis altirostris*  
*S. brevifrons*  
*Taenianotus triacanthus*

**Serranidae (Anthiinae)**

*Anthias thompsoni*  
*Pseudanthias winniensis*

**Sphyraenidae**

*Sphyraena japonicus*

**Stomiidae**

*Astronesthes* sp.

**Syngnathidae**

*Festucalex erythraeus*  
*Hippocampus kuda*

**Synodontidae**

Unidentified sp.  
*Saurida nebulosa*  
*Synodus amaranthus*  
*S. falcatus*  
*S. ulae*  
*S. usitatus*  
*Trachinocephalus myops*

**Tetraodontidae**

*Lagocephalus hypselogeneion*

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Appendix E.--Frequency and catch for all species caught during the Townsend Cromwell cruise TC-90-10 in the main Hawaiian Islands, 1990.

| Species                            | Frequency<br>(N trawls) | Total<br>N caught<br>(individuals) | Percent of<br>total No. |
|------------------------------------|-------------------------|------------------------------------|-------------------------|
| <i>Benthosema fibulatum</i>        | 40                      | 1401                               | 31.76                   |
| <i>Lagocephalus hypselogeneion</i> | 25                      | 851                                | 19.29                   |
| <i>Trachinocephalus myops</i>      | 45                      | 719                                | 16.30                   |
| <i>Engyproson xenandrus</i>        | 31                      | 228                                | 5.17                    |
| <i>Lutjanus kasmira</i>            | 11                      | 153                                | 3.47                    |
| <i>Pristipomoides filamentosus</i> | 12                      | 123                                | 2.79                    |
| <i>Synagrops argyrea</i>           | 14                      | 122                                | 2.77                    |
| <i>Heniochus diphreutes</i>        | 7                       | 107                                | 2.43                    |
| <i>Ariosoma bowersi</i>            | 25                      | 64                                 | 1.45                    |
| <i>Bleekeria gilli</i>             | 2                       | 64                                 | 1.45                    |
| <i>Dactyloptena orientalis</i>     | 14                      | 54                                 | 1.22                    |
| <i>Parupeneus chrysonemus</i>      | 14                      | 48                                 | 1.09                    |
| <i>Bothus thompsoni</i>            | 8                       | 35                                 | 0.79                    |
| <i>Synodus falcatus</i>            | 15                      | 29                                 | 0.66                    |
| <i>Lactoria</i> spp.               | 9                       | 25                                 | 0.57                    |
| <i>Gnatholepis anjerensis</i>      | 8                       | 21                                 | 0.48                    |
| <i>Priacanthus alalaua</i>         | 6                       | 20                                 | 0.45                    |
| <i>Iracundus signifer</i>          | 6                       | 19                                 | 0.43                    |
| <i>Canthigaster rivulatus</i>      | 10                      | 19                                 | 0.43                    |
| Bothidae (unidentified sp.)        | 5                       | 18                                 | 0.41                    |
| <i>Bothus pantherinus</i>          | 7                       | 18                                 | 0.41                    |
| <i>Chromis leucura</i>             | 4                       | 17                                 | 0.39                    |
| <i>Callionymus decoratus</i>       | 10                      | 17                                 | 0.39                    |
| <i>Parapercis schauinsland</i>     | 8                       | 15                                 | 0.34                    |
| <i>Mulloides auriflamma</i>        | 5                       | 14                                 | 0.32                    |
| <i>Fistularia petimba</i>          | 5                       | 14                                 | 0.32                    |
| <i>Ophidion muraenolepis</i>       | 4                       | 14                                 | 0.32                    |
| <i>Parupeneus pleurostigma</i>     | 7                       | 14                                 | 0.32                    |
| Synodontidae (unidentified sp.)    | 5                       | 14                                 | 0.32                    |
| <i>Canthigaster epilampra</i>      | 6                       | 12                                 | 0.27                    |
| <i>Scorpaena colorata</i>          | 8                       | 12                                 | 0.27                    |
| <i>Mulloides flavolineatus</i>     | 7                       | 11                                 | 0.25                    |
| <i>Chaetodon miliaris</i>          | 5                       | 9                                  | 0.20                    |
| <i>Decapterus macarellus</i>       | 5                       | 6                                  | 0.14                    |
| <i>Saurenhelys</i> sp.             | 5                       | 6                                  | 0.14                    |
| <i>Chromis verater</i>             | 3                       | 5                                  | 0.11                    |
| <i>Halieutaea retifera</i>         | 3                       | 5                                  | 0.11                    |
| <i>Myripristis chryseres</i>       | 2                       | 5                                  | 0.11                    |
| <i>Apogon maculiferus</i>          | 3                       | 4                                  | 0.09                    |
| <i>Antennarius striatus</i>        | 4                       | 4                                  | 0.09                    |
| <i>Canthigaster coronatus</i>      | 3                       | 4                                  | 0.09                    |
| Apogonidae (unidentified sp.)      | 2                       | 3                                  | 0.07                    |
| <i>Carapis homei</i>               | 3                       | 3                                  | 0.07                    |

## Appendix E.--Continued.

| Species                            | Frequency<br>(N trawls) | Total<br>N caught<br>(individuals) | Percent of<br>total No. |
|------------------------------------|-------------------------|------------------------------------|-------------------------|
| <i>Dasyatis</i> sp.                | 2                       | 3                                  | 0.07                    |
| Nomeidae (unidentified sp.)        | 1                       | 3                                  | 0.07                    |
| <i>Eurypegasus papilio</i>         | 2                       | 3                                  | 0.07                    |
| <i>Scorpaenopsis altirostris</i>   | 3                       | 3                                  | 0.07                    |
| <i>Scorpaenopsis brevifrons</i>    | 1                       | 3                                  | 0.07                    |
| <i>Oxycirrhites typus</i>          | 2                       | 3                                  | 0.07                    |
| <i>Anthias thompsoni</i>           | 2                       | 2                                  | 0.05                    |
| <i>Upeneus arge</i>                | 1                       | 2                                  | 0.05                    |
| <i>Apogon snyderi</i>              | 1                       | 2                                  | 0.05                    |
| <i>Centropyge potteri</i>          | 1                       | 2                                  | 0.05                    |
| <i>Hippocampus kuda</i>            | 2                       | 2                                  | 0.05                    |
| <i>Sphyræna japonicus</i>          | 2                       | 2                                  | 0.05                    |
| <i>Synodus ulae</i>                | 2                       | 2                                  | 0.05                    |
| <i>Taenianotus triacanthus</i>     | 2                       | 2                                  | 0.05                    |
| <i>Antigonia eos</i>               | 1                       | 1                                  | 0.02                    |
| <i>Amanses</i> (Cantherines) sp.   | 1                       | 1                                  | 0.02                    |
| <i>Apterichtus flavicaudus</i>     | 1                       | 1                                  | 0.02                    |
| <i>Sammariscus corallinus</i>      | 1                       | 1                                  | 0.02                    |
| <i>Astronesthes</i> sp.            | 1                       | 1                                  | 0.02                    |
| <i>Brotula multibarбата</i>        | 1                       | 1                                  | 0.02                    |
| <i>Centropyge fisheri</i>          | 1                       | 1                                  | 0.02                    |
| <i>Cheilinus bimaculatus</i>       | 1                       | 1                                  | 0.02                    |
| <i>Congrina aequorea</i>           | 1                       | 1                                  | 0.02                    |
| <i>Dendrochirus barberi</i>        | 1                       | 1                                  | 0.02                    |
| <i>Diodon hystrix</i>              | 1                       | 1                                  | 0.02                    |
| <i>Epigonus fragilis</i>           | 1                       | 1                                  | 0.02                    |
| <i>Festucalex erythraeus</i>       | 1                       | 1                                  | 0.02                    |
| <i>Foa brachygramma</i>            | 1                       | 1                                  | 0.02                    |
| <i>Chaetodon fremblii</i>          | 1                       | 1                                  | 0.02                    |
| Gempylidae (unidentified sp.)      | 1                       | 1                                  | 0.02                    |
| <i>Cirrhilabrus jordani</i>        | 1                       | 1                                  | 0.02                    |
| <i>Carcharhinus milberti</i>       | 1                       | 1                                  | 0.02                    |
| <i>Neomerinthe rufescens</i>       | 1                       | 1                                  | 0.02                    |
| Ophichthidae (unidentified sp.)    | 1                       | 1                                  | 0.02                    |
| <i>Physiculus</i> sp.              | 1                       | 1                                  | 0.02                    |
| <i>Cirrimuraena playfairii</i>     | 1                       | 1                                  | 0.02                    |
| <i>Pseudojuloides cerasinus</i>    | 1                       | 1                                  | 0.02                    |
| <i>Psilogobius mainlandi</i>       | 1                       | 1                                  | 0.02                    |
| <i>Pseudanthias winniensis</i>     | 1                       | 1                                  | 0.02                    |
| <i>Synodus amaranthus</i>          | 1                       | 1                                  | 0.02                    |
| <i>Sargocentron xantherythrum</i>  | 1                       | 1                                  | 0.02                    |
| <i>Pristipomoides sieboldii</i>    | 1                       | 1                                  | 0.02                    |
| <i>Synodus usitatus</i>            | 1                       | 1                                  | 0.02                    |
| <i>Gymnothorax flavomarginatus</i> | 1                       | 1                                  | 0.02                    |
| <i>Gymnothorax mucifer</i>         | 1                       | 1                                  | 0.02                    |



Appendix F.--Frequency and aggregate weight during the *Townsend Cromwell* cruise 90-10 in the main Hawaiian Islands, 1990, for each species caught.

| Species                                | Frequency<br>(No. trawls) | Aggregate weight |         |
|----------------------------------------|---------------------------|------------------|---------|
|                                        |                           | kg               | Percent |
| <i>Dasyatis</i> sp.                    | 2                         | 95.00            | 37.46   |
| <i>Lagocephalus hypselogeneion</i>     | 25                        | 73.89            | 29.14   |
| <i>Trachinocephalus myops</i>          | 45                        | 32.66            | 12.88   |
| <i>Lutjanus kasmira</i>                | 11                        | 10.47            | 4.13    |
| <i>Pristipomoides filamentosus</i>     | 12                        | 8.72             | 3.44    |
| <i>Carcharhinus milberti</i>           | 1                         | 4.04             | 1.59    |
| <i>Benthoosema fibulatum</i>           | 40                        | 3.92             | 1.55    |
| <i>Heniochus diphreutes</i>            | 7                         | 3.03             | 1.19    |
| <i>Ariosoma bowersi</i>                | 25                        | 2.18             | 0.86    |
| <i>Dactyloptena orientalis</i>         | 14                        | 2.18             | 0.86    |
| <i>Parupeneus chrysonemus</i>          | 14                        | 1.56             | 0.62    |
| <i>Mulloides auriflamma</i>            | 5                         | 1.48             | 0.58    |
| <i>Synagrops argyrea</i>               | 14                        | 1.31             | 0.52    |
| <i>Mulloides flavolineatus</i>         | 7                         | 1.30             | 0.51    |
| <i>Chromis verater</i>                 | 3                         | 1.27             | 0.50    |
| <i>Bothus pantherinus</i>              | 7                         | 0.91             | 0.36    |
| <i>Diodon hystrix</i>                  | 1                         | 0.87             | 0.34    |
| <i>Lactoria</i> spp.                   | 9                         | 0.82             | 0.32    |
| <i>Gymnothorax flavomarginatus</i>     | 1                         | 0.80             | 0.32    |
| <i>Bleekeria gilli</i>                 | 2                         | 0.79             | 0.31    |
| <i>Priacanthus alalaua</i>             | 6                         | 0.70             | 0.28    |
| <i>Engyprosopon xenandrus</i>          | 31                        | 0.60             | 0.24    |
| <i>Bothus thompsoni</i>                | 8                         | 0.54             | 0.21    |
| <i>Parupeneus pleurostigma</i>         | 7                         | 0.50             | 0.20    |
| <i>Canthigaster rivulatus</i>          | 10                        | 0.49             | 0.19    |
| <i>Chaetodon miliaris</i>              | 5                         | 0.39             | 0.15    |
| <i>Synodus falcatus</i>                | 15                        | 0.36             | 0.14    |
| <i>Decapterus macarellus</i>           | 5                         | 0.35             | 0.14    |
| <i>Upeneus arge</i>                    | 1                         | 0.27             | 0.11    |
| <i>Fistularia petimba</i>              | 5                         | 0.27             | 0.11    |
| <i>Synodus ulae</i>                    | 2                         | 0.16             | 0.06    |
| <i>Sphyræna japonicus</i>              | 2                         | 0.15             | 0.06    |
| <i>Synodontidae</i> (unidentified sp.) | 5                         | 0.13             | 0.05    |
| <i>Anthias thompsoni</i>               | 2                         | 0.12             | 0.05    |
| <i>Iracundus signifer</i>              | 6                         | 0.12             | 0.05    |
| <i>Ophidion muraenolepis</i>           | 4                         | 0.12             | 0.05    |
| <i>Nomeidae</i> (unidentified sp.)     | 1                         | 0.10             | 0.04    |
| <i>Gymnothorax mucifer</i>             | 1                         | 0.10             | 0.04    |
| <i>Bothidae</i> (unidentified sp.)     | 5                         | 0.09             | 0.04    |
| <i>Brotula multibarbata</i>            | 1                         | 0.09             | 0.04    |
| <i>Chromis leucura</i>                 | 4                         | 0.09             | 0.04    |
| <i>Callionymus decoratus</i>           | 10                        | 0.08             | 0.03    |
| <i>Halieutaea retifera</i>             | 3                         | 0.08             | 0.03    |
| <i>Canthigaster coronatus</i>          | 3                         | 0.07             | 0.03    |

## Appendix F.--Continued.

| Species                           | Frequency<br>(No. trawls) | Aggregate weight |         |
|-----------------------------------|---------------------------|------------------|---------|
|                                   |                           | kg               | Percent |
| <i>Canthigaster epilampra</i>     | 6                         | 0.07             | 0.03    |
| <i>Chaetodon fremblii</i>         | 1                         | 0.06             | 0.02    |
| <i>Antennarius striatus</i>       | 4                         | 0.05             | 0.02    |
| <i>Pristipomoides sieboldii</i>   | 1                         | 0.05             | 0.02    |
| <i>Parapercis schauinslandi</i>   | 8                         | 0.03             | 0.01    |
| <i>Sargocentron xantherythrum</i> | 1                         | 0.03             | 0.01    |
| <i>Apogon maculiferus</i>         | 3                         | 0.02             | 0.01    |
| <i>Apogon snyderi</i>             | 1                         | 0.02             | 0.01    |
| <i>Centropyge potteri</i>         | 1                         | 0.02             | 0.01    |
| <i>Sammariscus corallinus</i>     | 1                         | 0.01             | 0.00    |
| <i>Congrina aequorea</i>          | 1                         | 0.01             | 0.00    |
| <i>Myripristis chryseres</i>      | 2                         | 0.01             | 0.00    |
| <i>Eurypegus papilio</i>          | 2                         | 0.01             | 0.00    |
| <i>Scorpaenopsis altirostris</i>  | 3                         | 0.01             | 0.00    |
| <i>Scorpaena colorata</i>         | 8                         | 0.01             | 0.00    |
| <i>Antigonia eos</i>              | 1                         | <0.01            | 0.00    |
| <i>Amanses (Cantherines) sp.</i>  | 1                         | <0.01            | 0.00    |
| Apogonidae (unidentified sp.)     | 2                         | <0.01            | 0.00    |
| <i>Apterichthys flavicaudus</i>   | 1                         | <0.01            | 0.00    |
| <i>Astronesthes sp.</i>           | 1                         | <0.01            | 0.00    |
| <i>Centropyge fisheri</i>         | 1                         | <0.01            | 0.00    |
| <i>Cheilinus bimaculatus</i>      | 1                         | <0.01            | 0.00    |
| <i>Carapis homei</i>              | 3                         | <0.01            | 0.00    |
| <i>Dendrochirus barberi</i>       | 1                         | <0.01            | 0.00    |
| <i>Epigonus fragilis</i>          | 1                         | <0.01            | 0.00    |
| <i>Festucalex erythraeus</i>      | 1                         | <0.01            | 0.00    |
| <i>Foa brachygramma</i>           | 1                         | <0.01            | 0.00    |
| Gempylidae (unidentified sp.)     | 1                         | <0.01            | 0.00    |
| <i>Gnatholepis anjerensis</i>     | 8                         | <0.01            | 0.00    |
| <i>Hippocampus kuda</i>           | 2                         | <0.01            | 0.00    |
| <i>Cirrhitilabrus jordani</i>     | 1                         | <0.01            | 0.00    |
| <i>Saurenhelys sp.</i>            | 5                         | <0.01            | 0.00    |
| <i>Neomerinthe rufescens</i>      | 1                         | <0.01            | 0.00    |
| Ophichthidae (unidentified sp.)   | 1                         | <0.01            | 0.00    |
| <i>Physiculus sp.</i>             | 1                         | <0.01            | 0.00    |
| <i>Cirrimuraena playfairii</i>    | 1                         | <0.01            | 0.00    |
| <i>Pseudojuloides cerasinus</i>   | 1                         | <0.01            | 0.00    |
| <i>Psilogobius mainlandi</i>      | 1                         | <0.01            | 0.00    |
| <i>Pseudanthias winniensis</i>    | 1                         | <0.01            | 0.00    |
| <i>Synodus amaranthus</i>         | 1                         | <0.01            | 0.00    |
| <i>Scorpaenopsis brevifrons</i>   | 1                         | <0.01            | 0.00    |
| <i>Synodus usitatus</i>           | 1                         | <0.01            | 0.00    |
| <i>Taenianotus triacanthus</i>    | 2                         | <0.01            | 0.00    |
| <i>Oxycirrhites typus</i>         | 2                         | <0.01            | 0.00    |







